

What is claimed is:

1. A gas-impermeable, mixed electron- and ion-conducting membrane consisting essentially of a porous electron-conducting matrix impregnated with a salt which is molten at membrane operating temperatures.
2. The membrane of claim 1 which has a central region wherein the porosity is sufficiently fine to substantially retain molten salt in the pores therein, and external regions wherein the porosity is sufficiently greater than in the central region such that the pores in these regions are not substantially filled with molten salt.
3. The membrane of claim 1 wherein a sufficient amount of molten salt is impregnated into the electron-conducting matrix to facilitate ion transport through the membrane.
4. The membrane of claim 1 wherein the electron-conducting matrix is formed from the group of transition metals or mixtures thereof.
5. The membrane of claim 4 wherein the metal is nickel or a mixture of nickel with another transition metal.
6. The mixed conducting membrane of claim 1 wherein the molten salt is a carbonate salt.
7. The mixed conducting membrane of claim 1 wherein the carbonate salt is a alkali metal carbonate, an alkaline earth metal carbonate or mixtures thereof.
8. The mixed conducting membrane of claim 7 wherein the molten carbonate is a lithium carbonate, a potassium carbonate or mixtures thereof.

9. The membrane of claim 1 wherein the electron-conducting matrix is an electron-conducting ceramic.
10. The membrane of claim 1 which comprises a plurality of layers of different porosity.
11. The membrane of claim 1 which comprises a first and a second external region on either side of a central region each external surface having an inside surface in contact with the central region and an outside surface forming either a reducing surface or an oxidizing surface of the membrane wherein the porosity of the central region is sufficiently fine to substantially retain molten salt in the pores therein, and wherein the porosity of the external regions is sufficiently greater than in the central region such that the pores in these regions are not substantially filled with molten salt.
12. The membrane of claim 11 wherein the average pore size in the central region is less than 1 micron and wherein the average pore size in the external regions is greater than 1 micron.
13. The membrane of claim 11 wherein the molten salt is a carbonate, halide, phosphate, sulfate or nitrate salt.
14. The membrane of claim 11 wherein the oxidation surface of the membrane is provided with an adherent oxidation catalyst layer.
15. The membrane of claim 14 wherein the adherent catalyst layer comprises a steam reforming catalyst.
16. The membrane of claim 11 wherein the reduction surface of the membrane is provided with a reduction catalyst.

17.

A membrane reactor comprising one or more membranes of claim 1.

18.

A membrane reactor for the separation of carbon dioxide from a gas containing carbon dioxide in the presence of oxygen and the partial oxidation of a reactant gas which comprises:

one or more gas-impermeable membranes of claim 1;

a reduction zone in contact with the reducing surface of the membrane for receiving a gas containing carbon dioxide and oxygen; and

an oxidation zone in contact with the oxidation surface of the membrane for receiving a reactant gas;

wherein the gas impermeable membrane separates the reduction zone from the oxidation zone.

19.

The membrane reactor of claim 18 further comprising an oxidation catalyst in the oxidation zone of the reactor in proximity to the oxidation surface of the membrane.

20.

The membrane reactor of claim 19 further comprising a reduction catalyst in the reduction zone of the reactor in proximity to the oxidation surface of the membrane.

21.

The membrane reactor of claim 18 which comprises a plurality of gas-impermeable membranes.

22.

The membrane reactor of claim 18 wherein the gas containing carbon dioxide and oxygen is air.

23.

The membrane reactor of claim 18 wherein the reduced gas comprises methane, a lower hydrocarbon or naphtha.

24. The membrane reactor of claim 18 wherein the reactor further comprises a steam reforming catalyst in the oxidation zone of the reactor and the reduced gas further comprises water.
25. The membrane reactor of claim 24 wherein the steam reforming catalyst is nickel or a nickel-based alloy supported on alumina, titania, silica or zirconia.
26. The membrane reactor of claim 23 wherein the steam reforming catalyst is nickel supported on alumina.
27. The membrane reactor of claim 18 further comprising a three-dimensional catalyst in close proximity to a membrane external surface.
28. A method for partially oxidizing a reduced gas which comprises the steps of:
- providing a membrane reactor of claim 18;
 - introducing a gas containing carbon dioxide and oxygen into the reduction zone of the reactor;
 - heating the membrane of the reactor to a temperature such that carbonate ion is formed at the reduction surface of the membrane, and transported through the
 - mixed conducting membrane to the oxidation surface; *AND*
 - introducing a reduced gas to the oxidation zone of the reactor which is partially oxidized by reaction with carbonate ion at the oxidation surface of said membrane.
29. The method of claim 28 wherein the reactor further comprises an oxidation catalyst in the oxidation zone of the reactor.
30. The method of claim 28 wherein the reduced gas comprises a hydrocarbon.

31. The method of claim 28 wherein the reduced gas comprises an alkene, an alkyne or an aromatic compound.
32. The method of claim 28 wherein the reduced gas is an epoxide, an aldehyde, a ketone, an alcohol or an amine or mixture thereof.
33. A membrane reactor for generating a reactive ion from a source gas which comprises:
the gas impermeable mixed conducting membrane of claim 1 wherein the molten salt is selected for mediation of the reactive ion;
a reagent zone in contact with a first external surface of the membrane for receiving an ion source gas; and
a reaction zone in contact with a second external surface of the membrane for receiving a reactant gas;
wherein the gas impermeable membrane separates the reagent zone from the reactant zone.
34. The membrane reactor of claim 33 wherein the reagent zone is an oxidation zone and the reactant zone is a reduction zone.
35. The membrane reactor of claim 33 wherein the reactive ion is a carbonate, a halide, a nitrate, a sulfate, a phosphate or an ammonium ion.
36. The membrane reactor of claim 34 wherein a three-dimensional catalyst is provided in the oxidation zone, the reduction zone or both.
37. A method for generating products by reaction of a reactive ion which comprises the steps of:
providing a membrane reactor of claim 33;
introducing a ion source gas into the reduction zone of the reactor;

heating the membrane of the reactor to a temperature such that the a reactive anion is formed at the reduction surface of the membrane, and transported through the mixed conducting membrane to the oxidation surface; *AND*

introducing a reactant gas to the oxidation zone of the reactor which undergoes reaction with the reactive ion at the oxidation surface of the membrane.

38. A method for generating products by reaction of a reactive ion which comprises the steps of:

providing a membrane reactor of claim 33;

introducing an ion source gas into the oxidation zone of the reactor;

heating the membrane of the reactor to a temperature such that a reactive cation is formed at the oxidation surface of the membrane, and transported through the mixed conducting membrane to the oxidation surface; *AND*

introducing a reactant gas to the reduction zone of the reactor which undergoes reaction with the reactive cation at the reduction surface of the membrane.

39. A method for making synthesis gas which comprises the steps of :

providing a membrane reactor of claim 33;

introducing an ion source gas for generation of carbonate ion into the oxidation zone of the reactor to generate carbonate ions;

heating the membrane to generate carbonate ion at the reduction surface of the membrane reactor and transport the carbonate ion through the membrane; *AND*

introducing a reactant gas comprising methane or other volatile hydrocarbon to the reduction zone of the reactor in contact with the membrane to react with carbonate ion to produce synthesis gas.

40. The method of claim 39 wherein the reactant gas further comprises steam and a steam reforming catalyst is provided as an adherent layer on a membrane external surface or as a

